

Energy Security in post-Paris Deep Decarbonisation Scenarios for the EU

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Context and motivation

During the COP21 in Paris (2015):

- 174 countries signed the Paris agreement setting the goal of limiting global warming to below 2°C.
- About 200 countries submitted Nationally Determined Contributions (NDC)

World and EU economy through 2°C and 1.5°C targets:

- What is the impact of Nationally Determined Contributions (NDC) on economy?
- Which steps are needed to attain these ambitious decarbonisation targets?
- Socio-economic consequences of climate policy and COP21 objectives.

RIPPLES project: **R**esults and **I**mplications for **P**athways and **P**olicies for **L**ow **E**missions European **S**ocieties

Energy security:

- What is the impact of mitigation scenarios on energy security?
- Which of climate scenario is the most suitable for the EU countries?

Energy Security definition

- Energy security is a complex concept with many definitions and a lot of indicators (Sovacool and Mukherjee, 2011)
- Energy security policies must ensure (IEA):
 - Uninterrupted availability of energy sources at an affordable price.
 - Cover or reduce risks that affect energy sector.
 - Sustainable development of economy.
- The best way of approaching the question of energy security is to identify and to describe the energy security dimensions.

Energy Security dimensions

- 1) **Availability** – the availability of energy resources, diversification and the energy (in)dependency.
- 2) **Affordability** – *“the capacity to produce energy services at the lowest cost, to have predictable energy prices and to enable equitable access to energy services”* (Sovacool and Mukherjee, 2011)
- 3) **Sustainability** – preserve and protect the environment and living conditions, tackle climate change. The effects should persist over time.
- 4) **Resilience to risks** – *“How the energy services can survive unexpected events that disrupt efficient operation?”* (Sovacool and Sanders, 2014)
- 5) **Economic development** – the ability of domestic economy to maintain or raise the standards of living
- 6) **Electricity grid reliability** – the capacity of power system to maintain the supply-demand equilibrium at any time.

Security dimensions and indicators in our study

Availability

- Energy diversity indexes, where p_i is a share of energy source or supplier:

- Shannon-Wiener Index.

$$SWI = -\sum_{i=1}^n p_i \log(p_i)$$

- Herfindahl–Hirschman Index.

$$HHI = \sum_{i=1}^n p_i^2$$

- Import dependency (ratio).

Affordability

- Energy bill per dwelling
- Energy prices

Electricity

- Capacity adequacy
- Share of solar and wind

Other indicators

- Reserve to production ratio
- Energy intensity
- Sustainability

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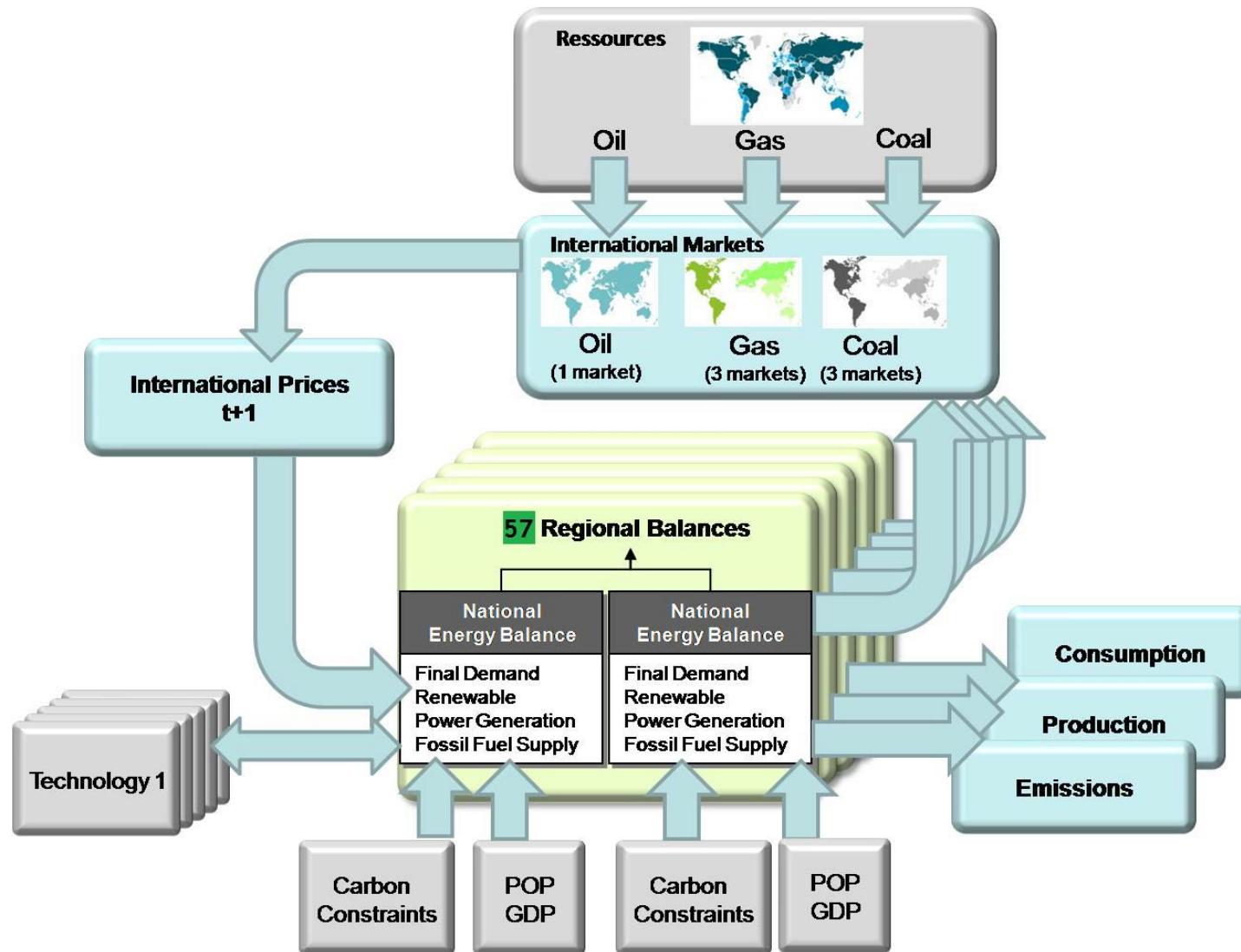
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POLES: year-by-year recursive simulation process



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Scenarios up to 2050

BAU: Until 2030 countries limit their ambition to the NDCs. For the period 2030-2050 we consider that carbon price remains the same as in 2030.

NDC 2°C : Until 2030 countries limit their ambition to the NDCs. The strong acceleration in climate policy are necessary after 2030 to reach 2°C target.

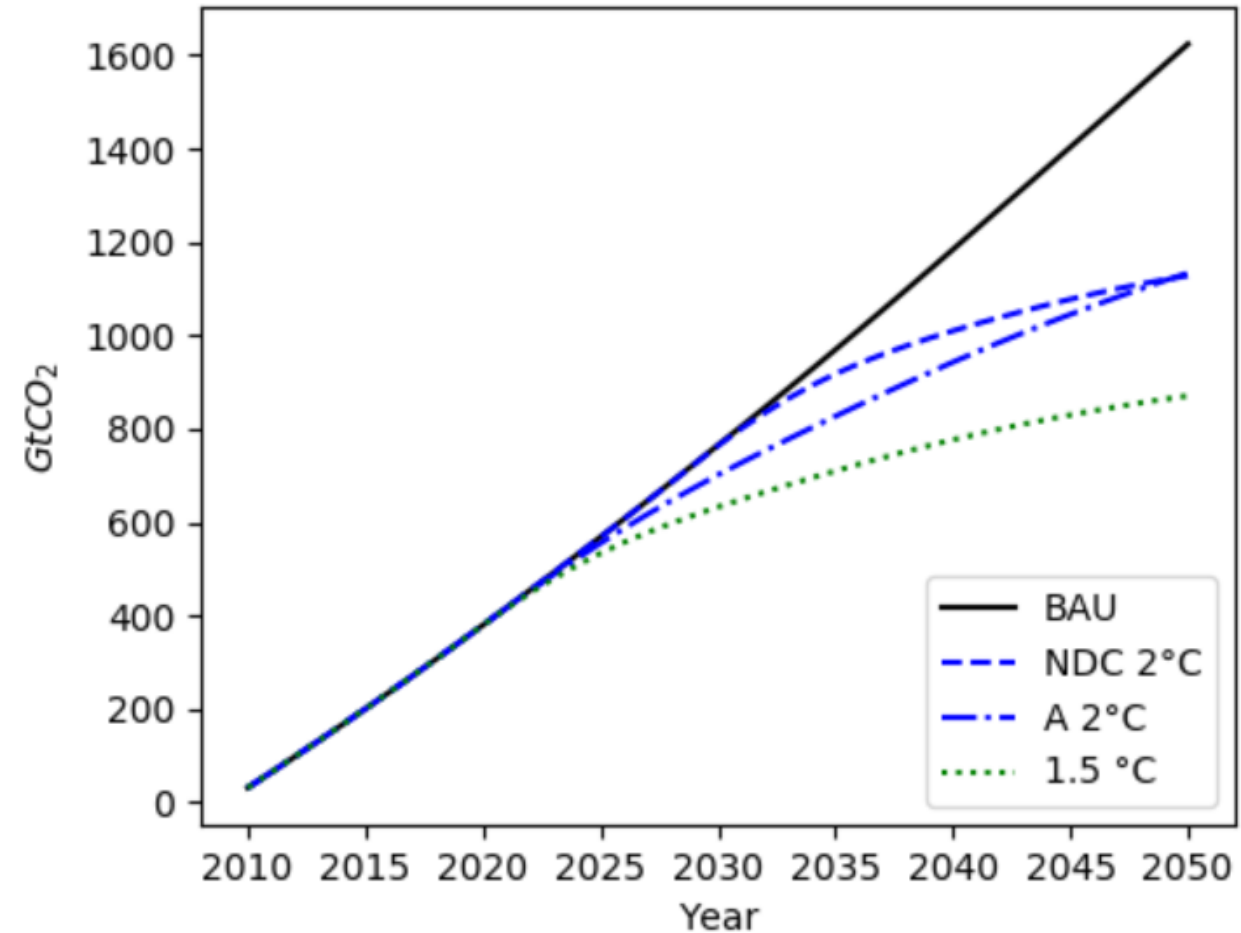
Accelerated 2°C: early climate policy action starts in 2020 and reaches the same carbon budget as in NDC 2°C.

1.5°C : ambitious climate policy starts in 2020 to reach 1.5°C

Scenarios:

	Carbon price 2050 (\$/tCO ₂)	Carbon budget 2011-2050 (GtCO ₂)
<i>BAU (5°C)</i>	2000-2030 (NDC 2°C) 5 – 60	1623
<i>NDC 2°C</i>	980	1130
<i>Accelerated 2°C</i>	558 High* 279 Middle** 139 Low ***	1130
<i>1.5°C</i>	1000	870

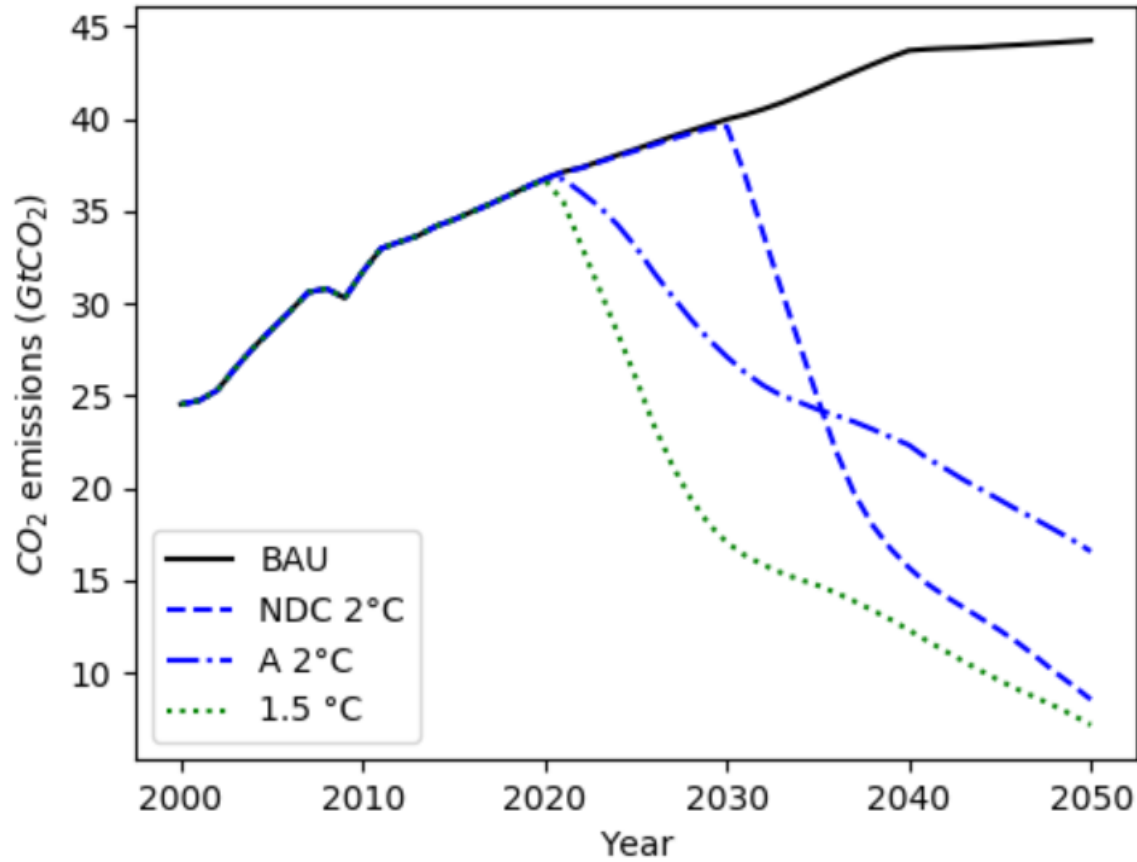
Cumulative CO₂ emissions (GtCO₂)



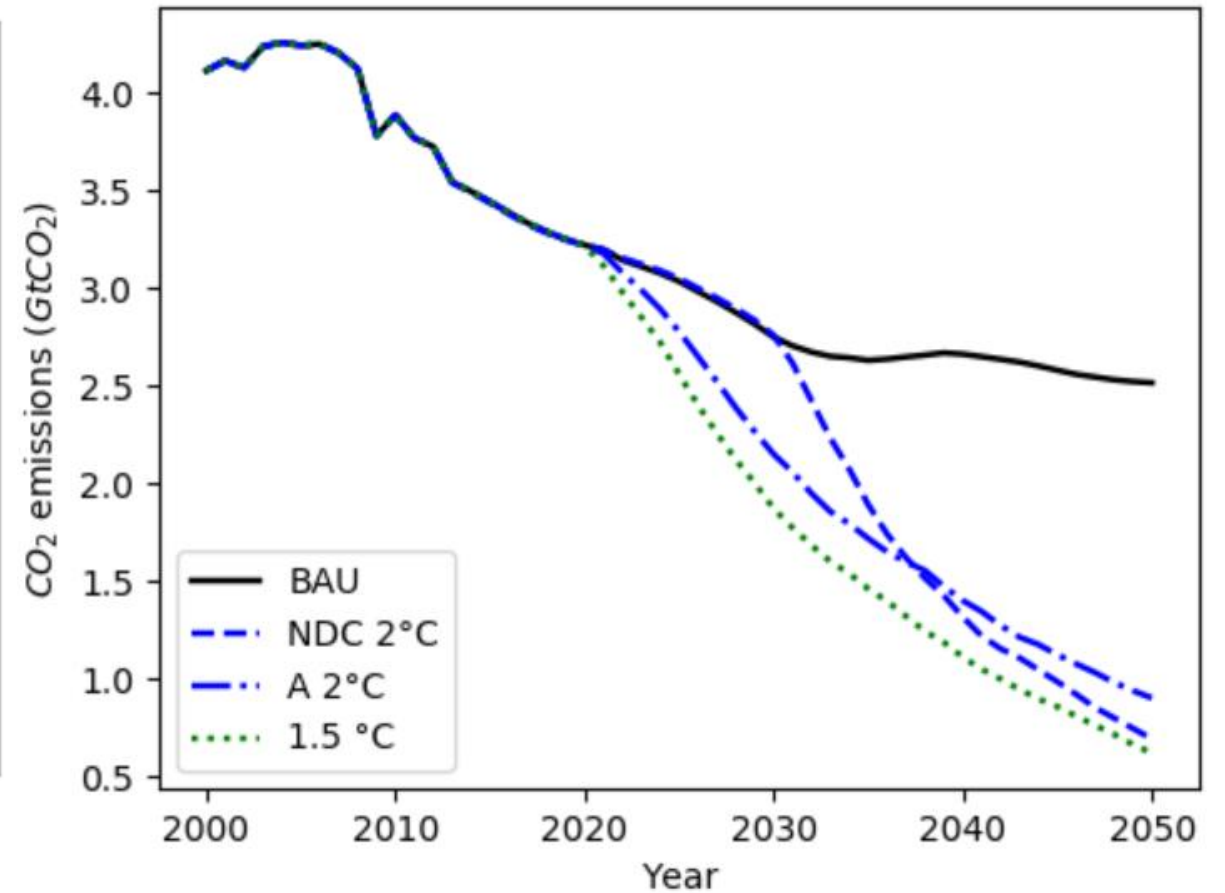
- * High: EU28*, USA, Canada, Norway, Island, Switzerland, Japan, Korea, RJAN (Australia, New Zealand).
- ** Middle: Turkey, Russia, Brazil, RSAM (other South America), China, South Africa.
- *** Low: the rest of the world.

CO₂ emissions

World CO₂ emissions (GtCO₂)



European CO₂ emissions (GtCO₂)



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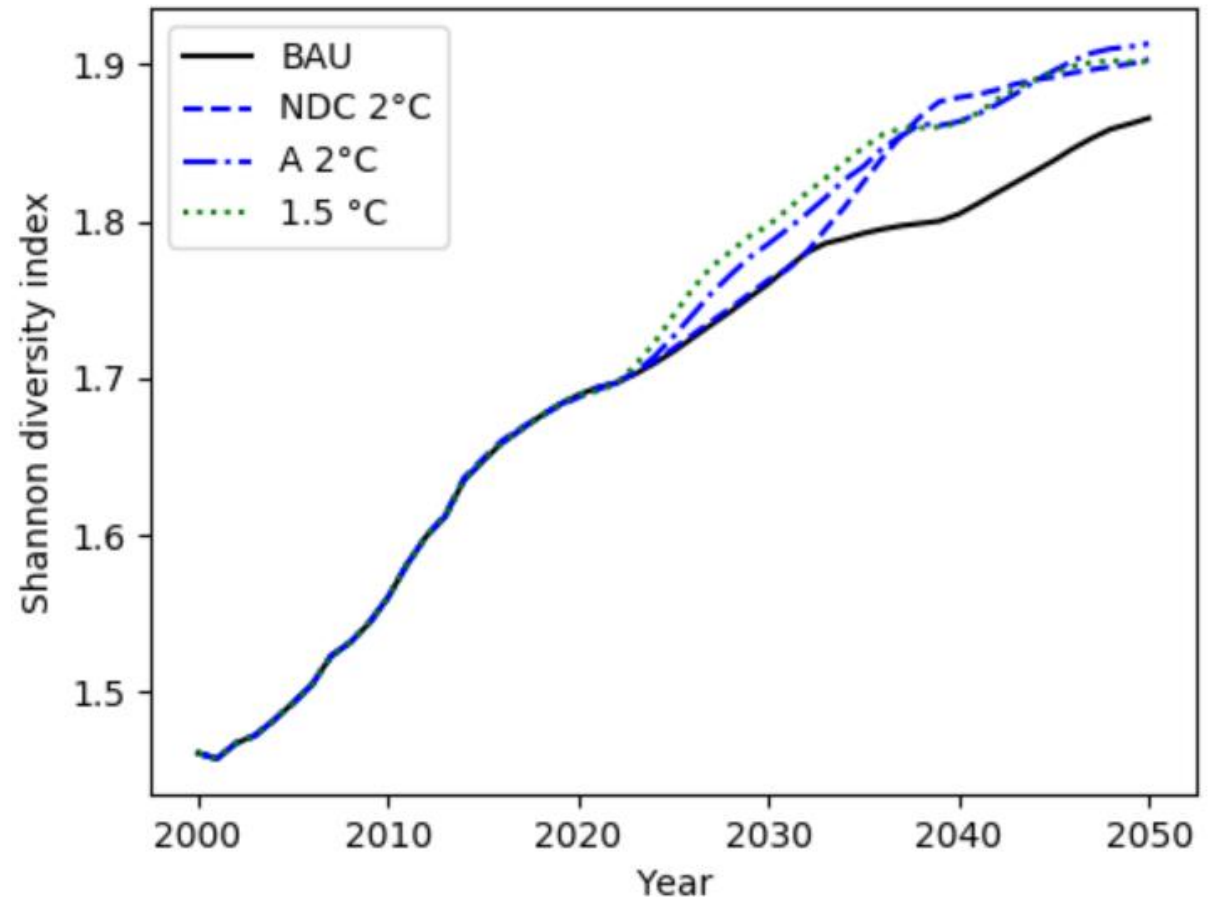
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Diversity of primary energy consumption

- Better diversity leads to more secure energy supply.
- The diversity of primary energy consumption increases in all European countries, even in BAU scenario. The increase is higher in mitigation scenarios (+2%)
- No difference between mitigation scenarios in all EU countries.

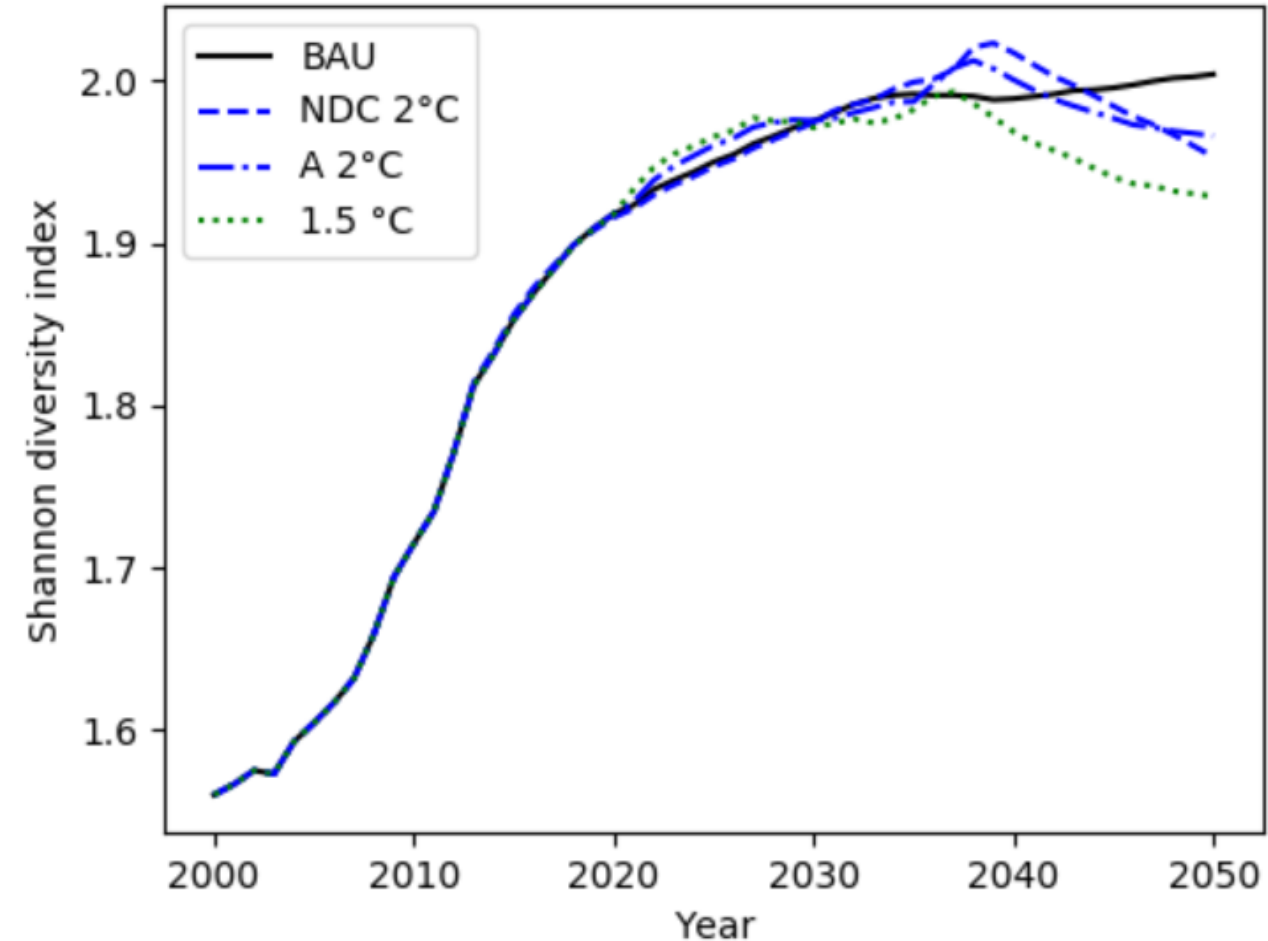
Diversity of primary energy consumption



Diversity of electricity generation

- The diversity of electricity generation increases in all scenarios stabilizing around 2 (the highest level of SDI is 2.3).
- The SDI decreases in mitigation scenarios from 2040 due to the low share of fossil fuels in electricity mix.
- Mitigation scenarios are not better or worse than BAU scenarios.
- Significant decrease in Ireland and Greece (high share of wind and solar)

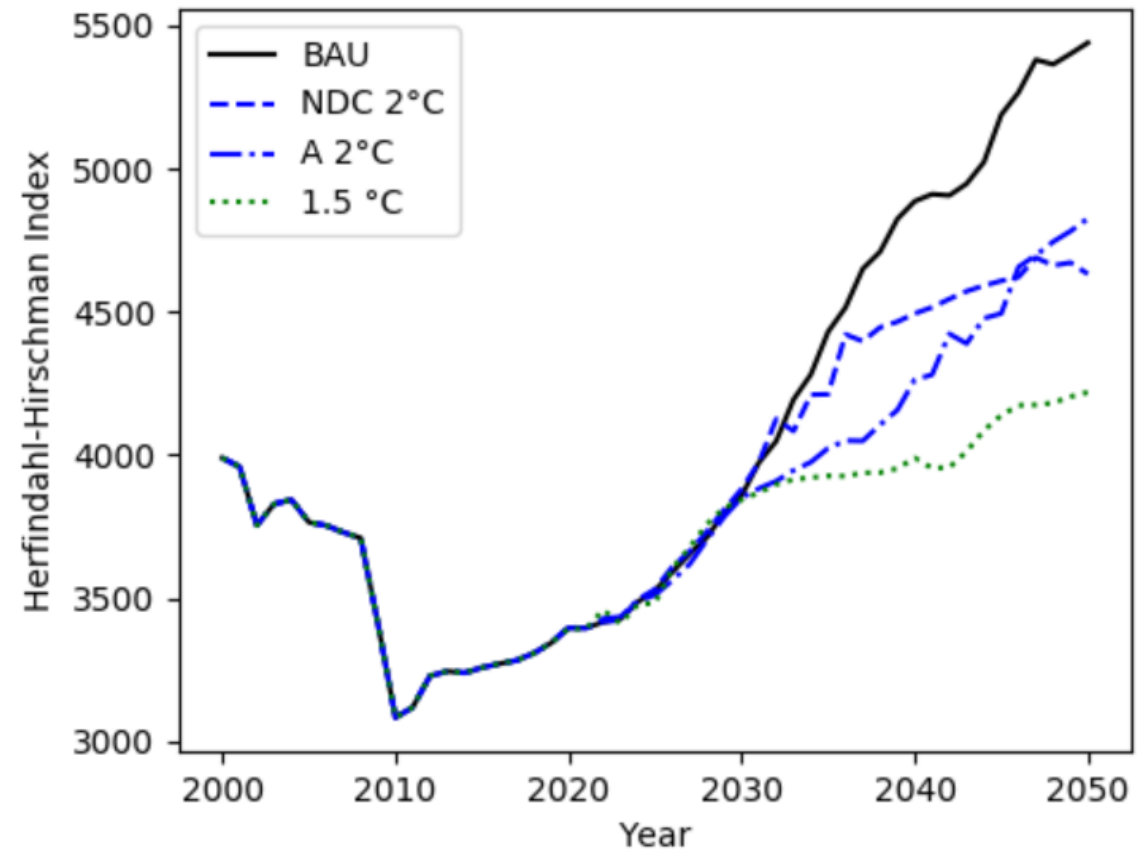
Diversity of electricity generation



Diversity of natural gas imports

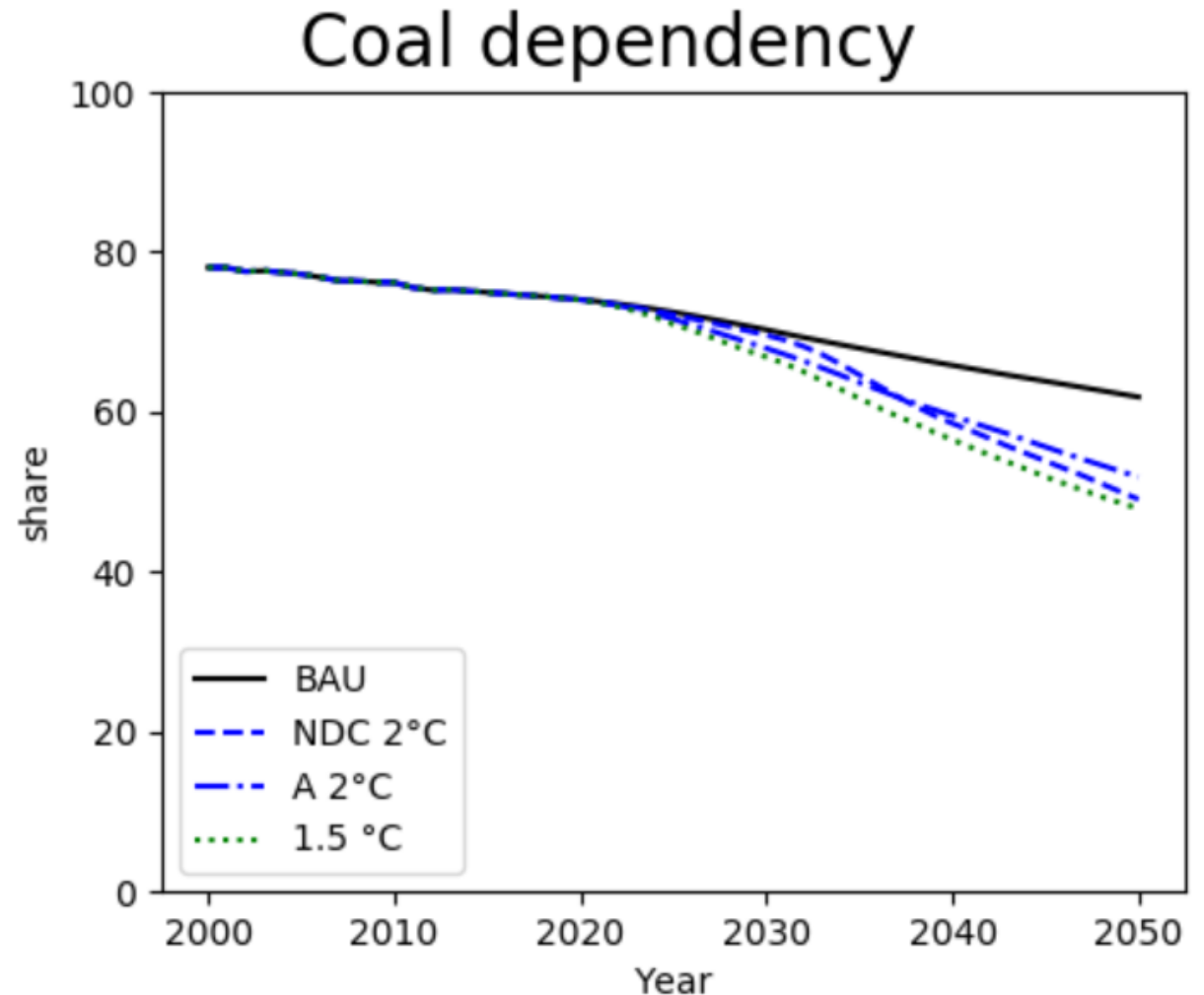
- Decrease of HHI leads to better competition.
- HHI increases in all scenarios after 2025 → Diversity of gas imports decrease gradually.
- Share of Russian gas imports is between 48% (1.5°C) and 55% (BAU). However the volume of Russian drops: -40% in 1.5°C compared to BAU.
- Country level: as POLES considers European gas market as single EU market, diversity of imports increase strongly in Estonia, Latvia, Lithuania, Bulgaria, Slovakia and Finland... but it is not the effect of mitigation scenarios.

Diversity of natural gas imports



Import dependency: share of imports

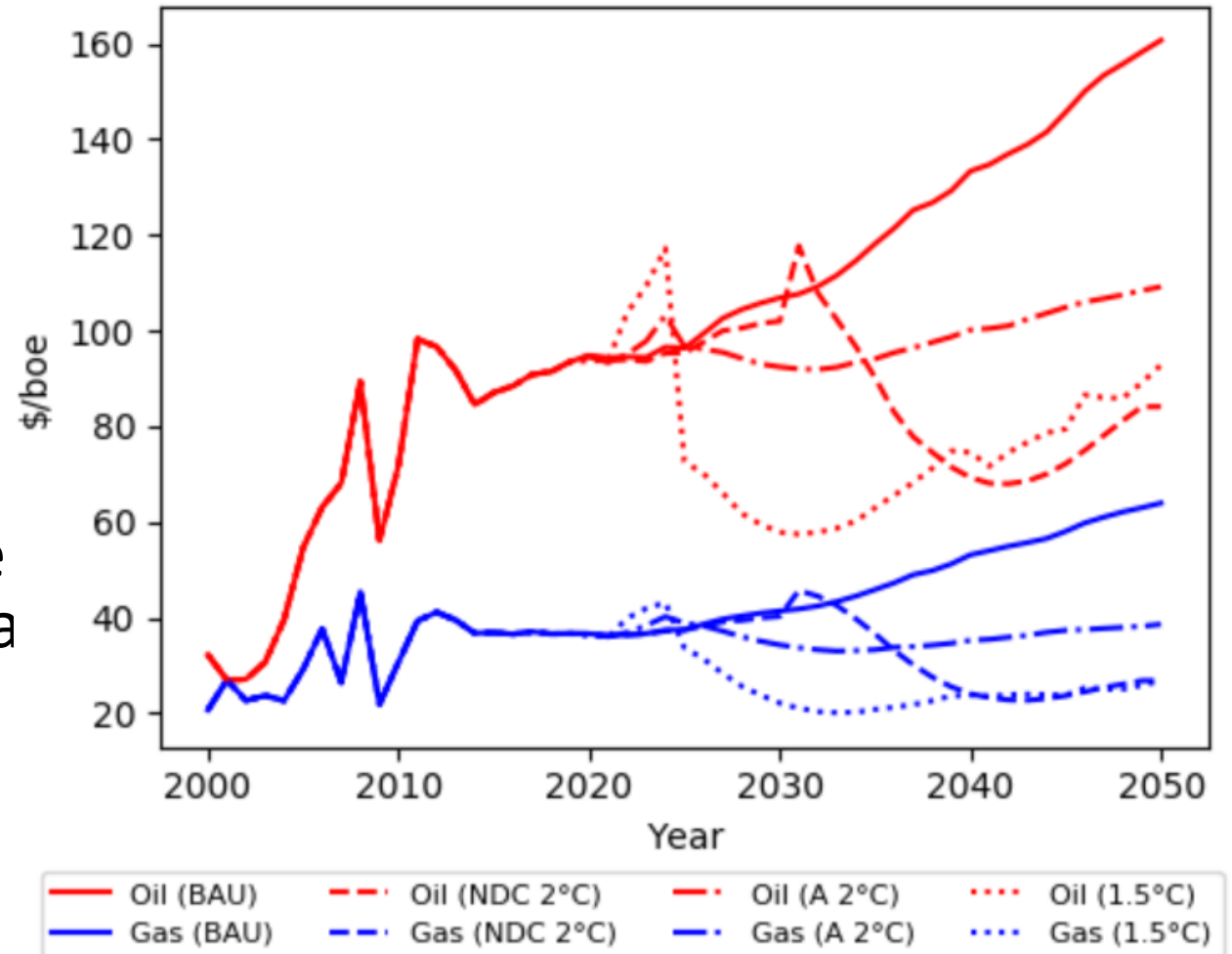
- Share of fossil fuel imports remains high in mitigation scenarios
- There is a small decrease of oil and natural gas dependency. This decrease may be high in 1.5°C if we assume technological breakthrough and change of behavior.
- Coal dependency has the biggest decrease due to mitigation scenarios.



Affordability: gas and oil prices

- The highest energy prices are observed in BAU scenario. Gas and oil prices increase.
- Oil and gas prices remain stable in Accelerated 2°C scenario with a small shock in 2020-2025.
- In NDC 2°C and 1.5°C scenarios the prices are lower, however there is a significant shock on oil and gas market due to quick introduction of ambitious climate policies.

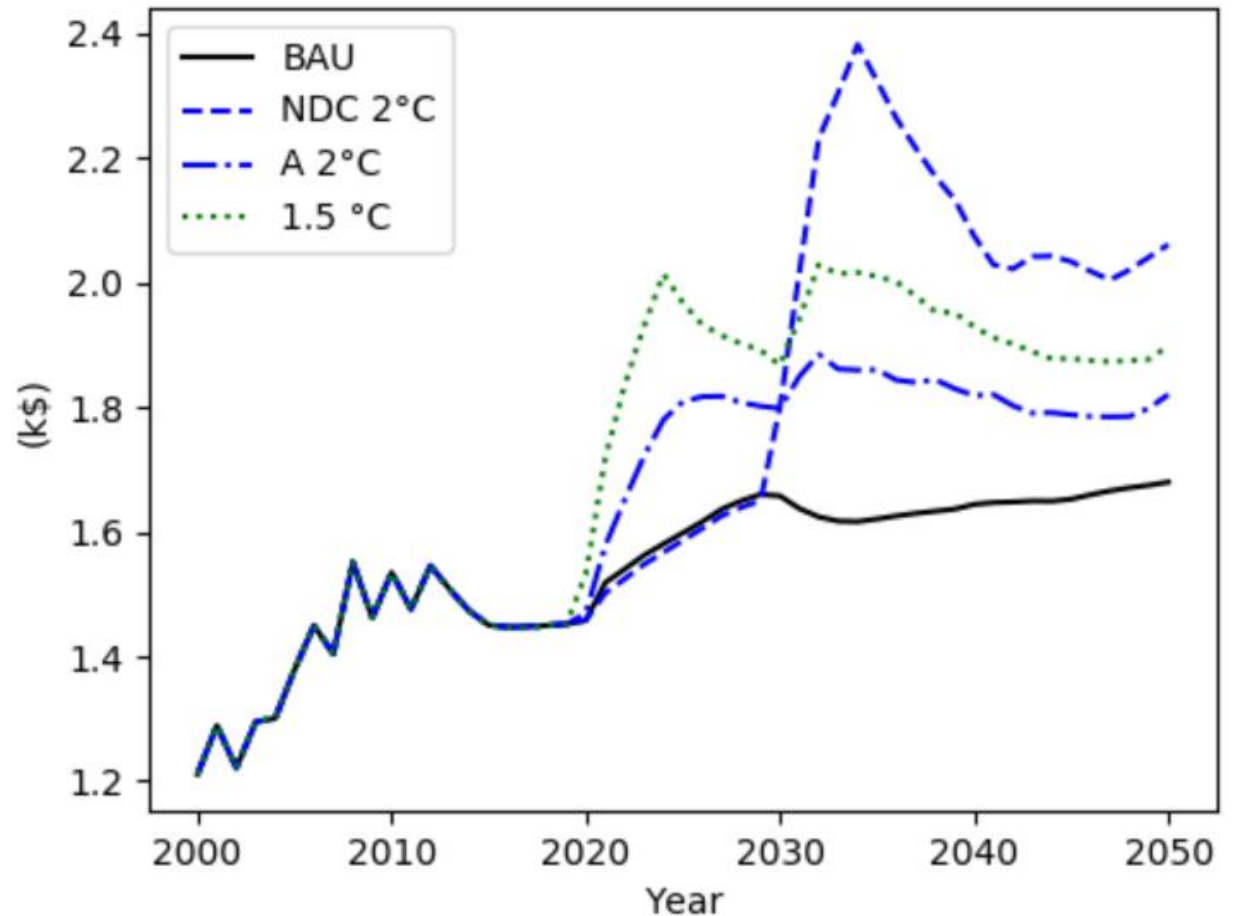
International energy prices



Affordability: energy bill per dwelling

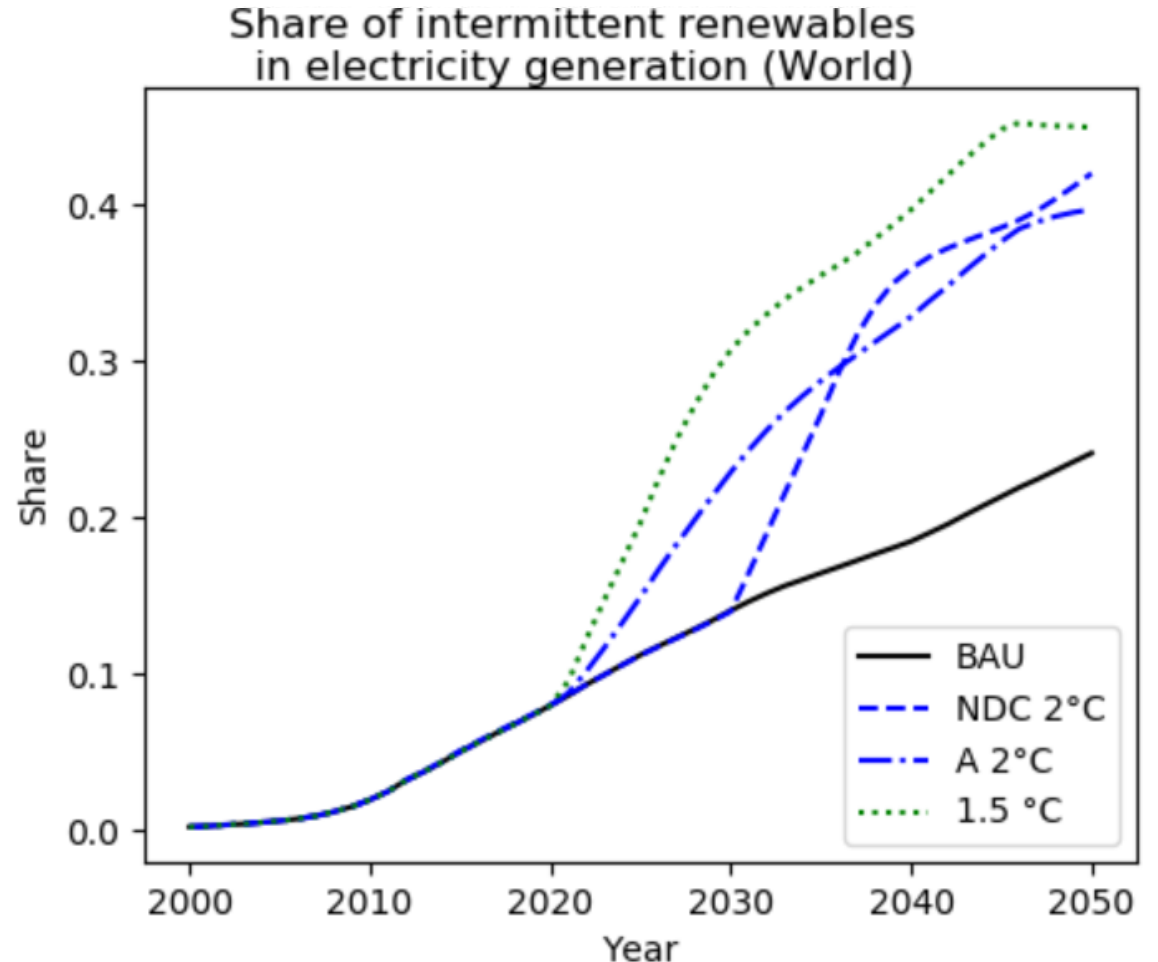
- POLES energy bill does not stand for exact amount of household energy spending.
- Shocks in gas and oil markets and ambitious climate policies lead to the fast increase of household energy bill per dwelling.
- We observe the highest increase in NDC 2°C scenario (+45%), followed by 1.5 °C (+33%) and A 2°C (+20%).
- Country level: Eastern countries are more vulnerable.

Energy bill per dwelling in EU28



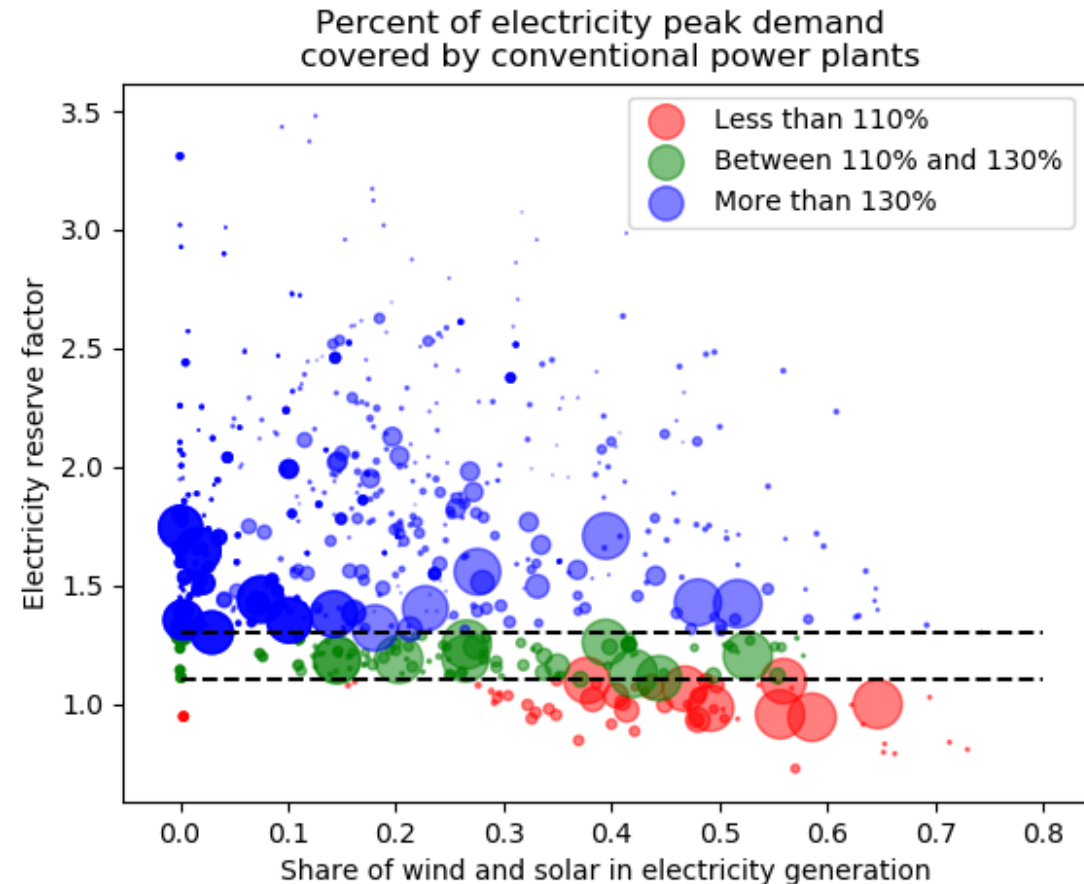
Share of wind and solar energy

- The average share of intermittent renewable sources is 35% in mitigation scenarios against 28% in BAU scenario.
- There is no difference between mitigations scenarios in the EU.
- The share of wind and solar increases more in non EU countries: biggest solar and wind potential.

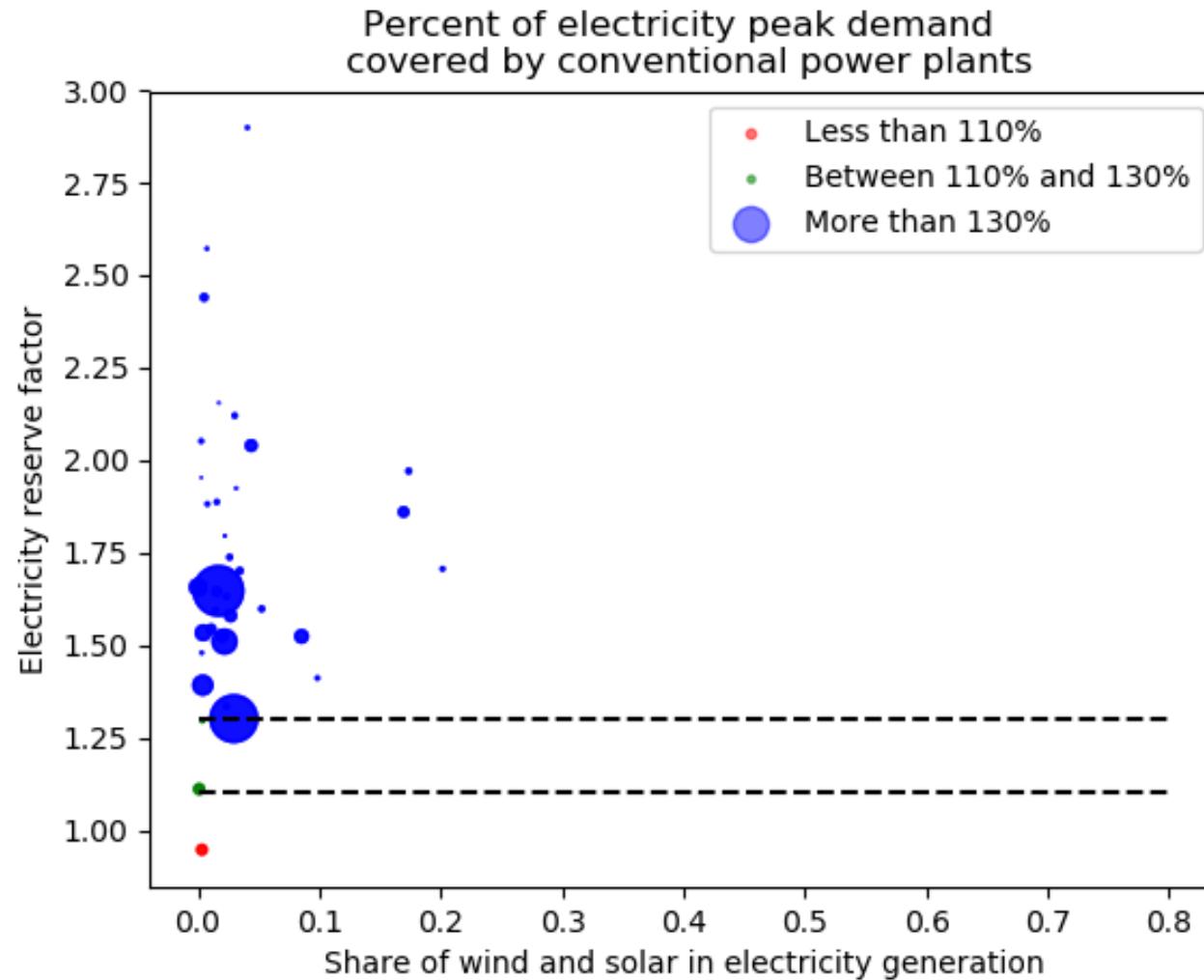


Reserve capacity factor

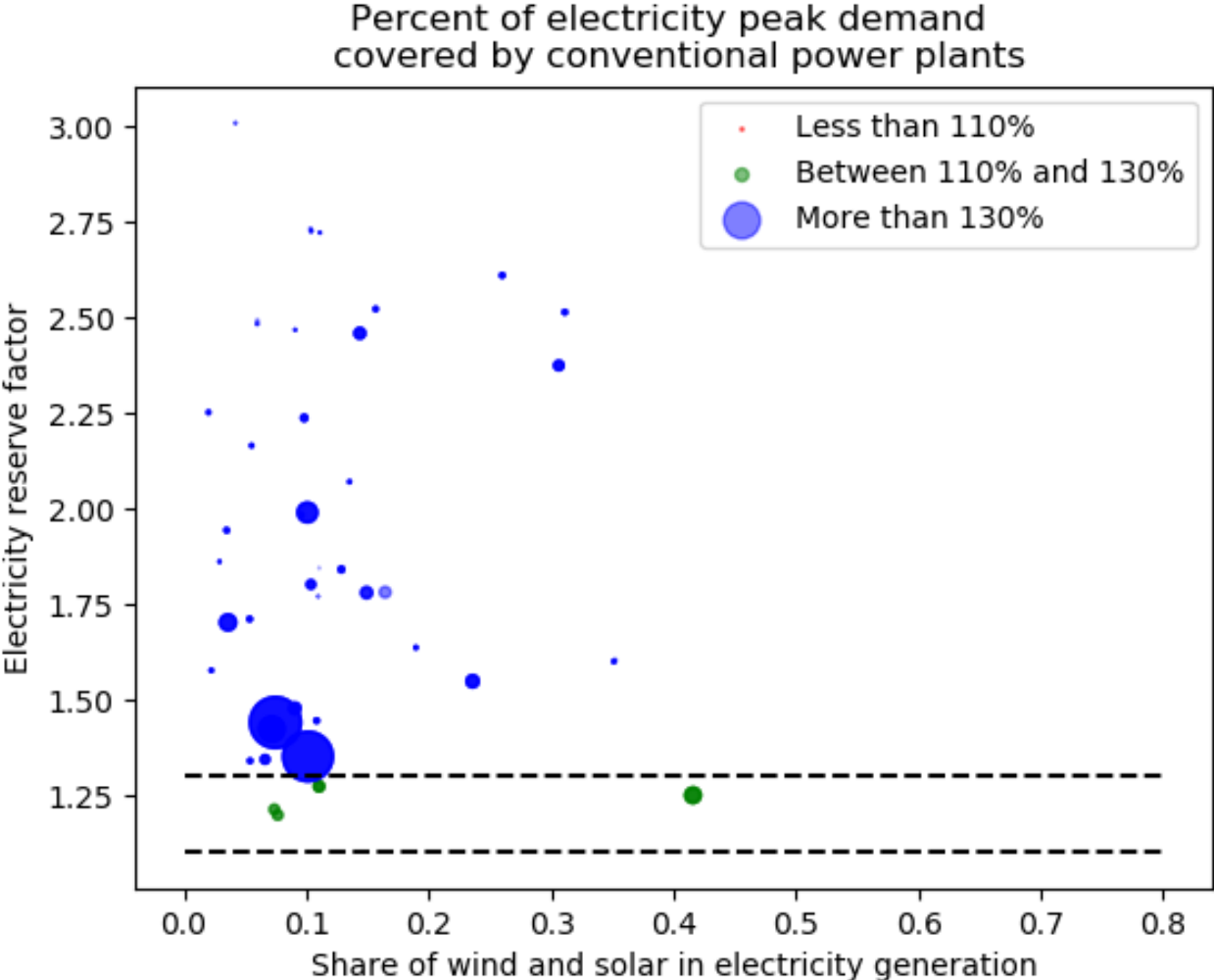
- Reserve capacity factor measure the level of peak demand covered by conventional plants in no-wind and no-solar conditions :
 - Conventional plants should cover 110%-130% of peak demand.
 - If less than 110% - risk of outage
 - If more than 130% - over investment
- POLES has a tendency to overinvest in power capacities.



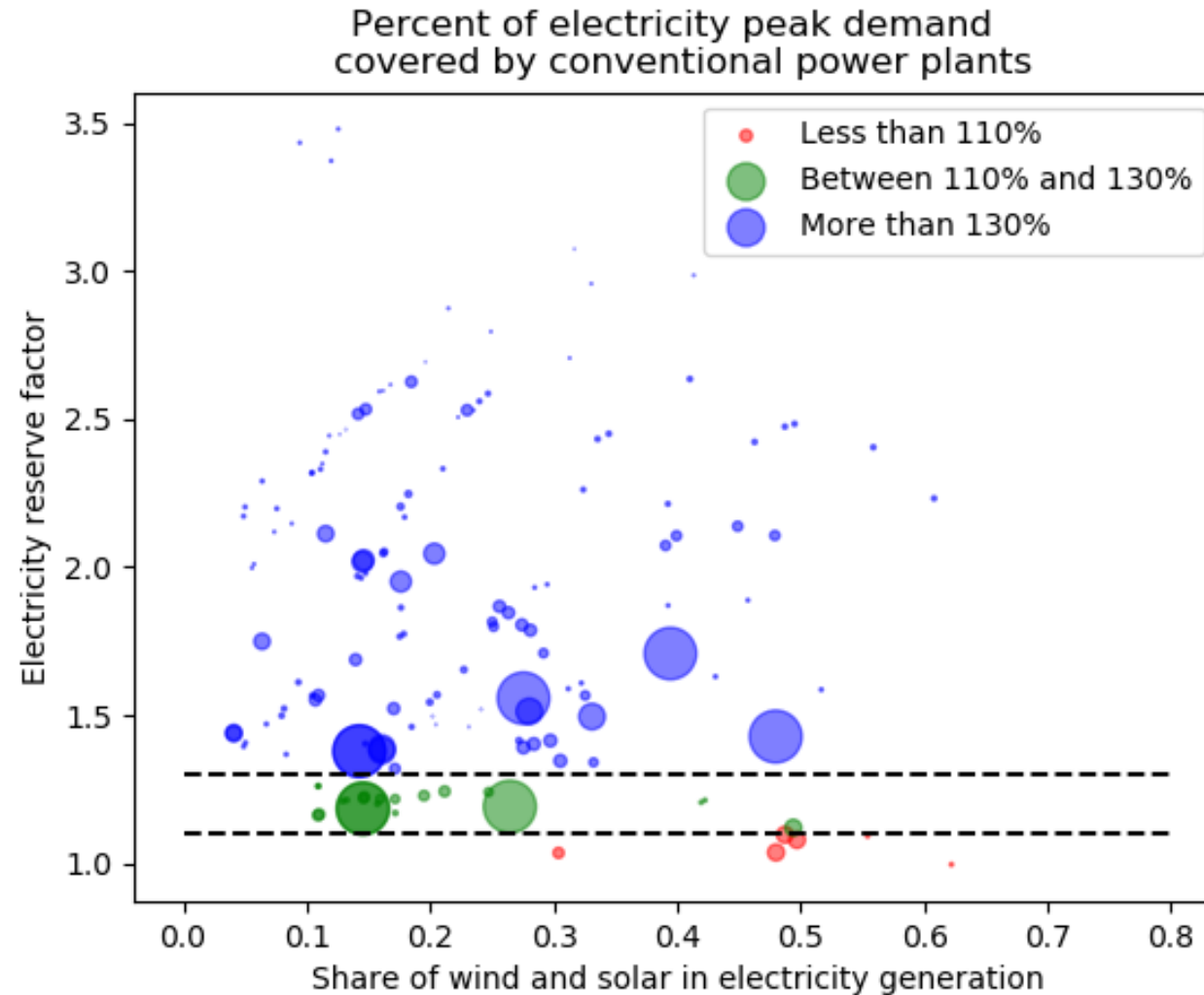
Reserve capacity factor 2010



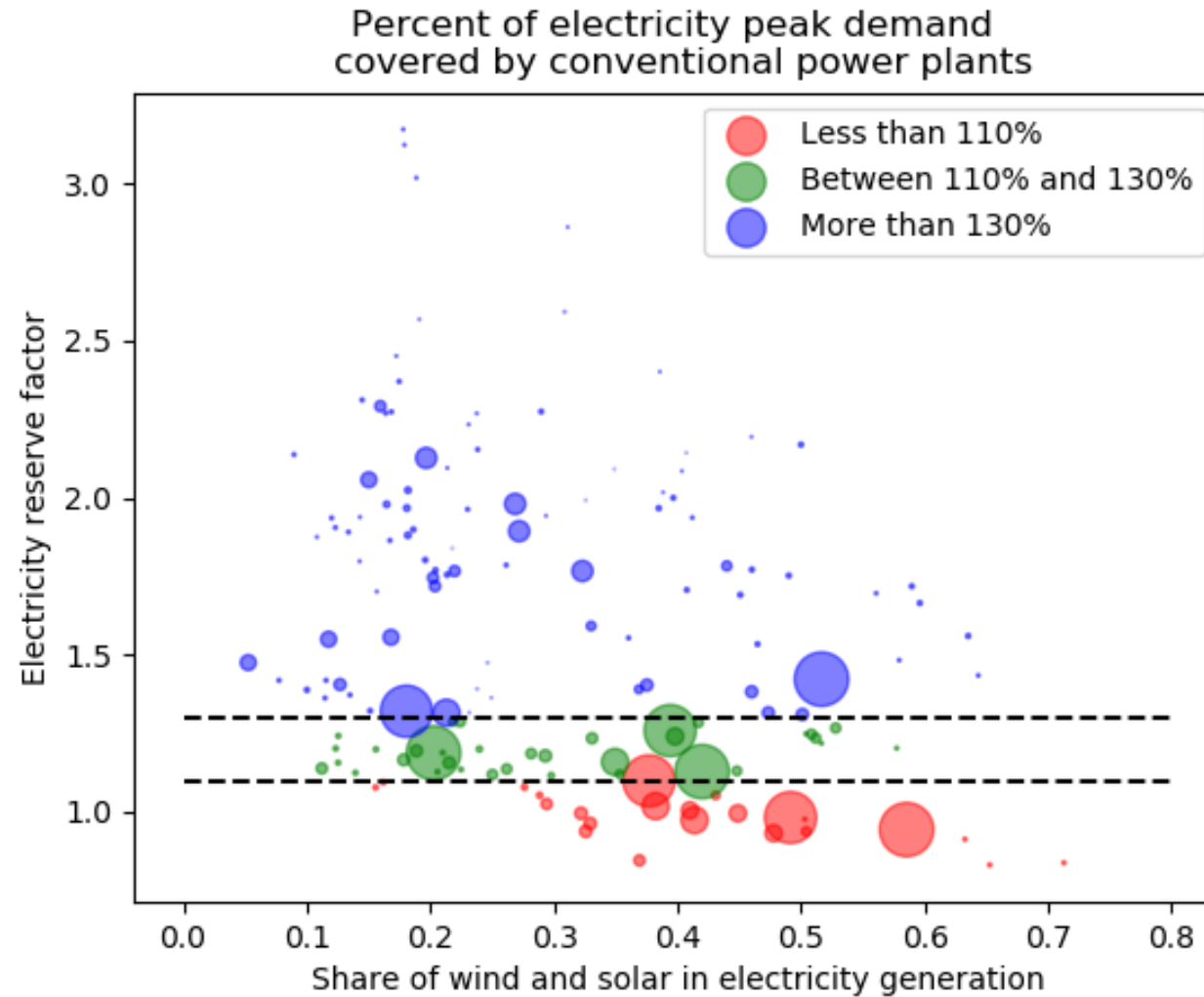
Reserve capacity factor 2020



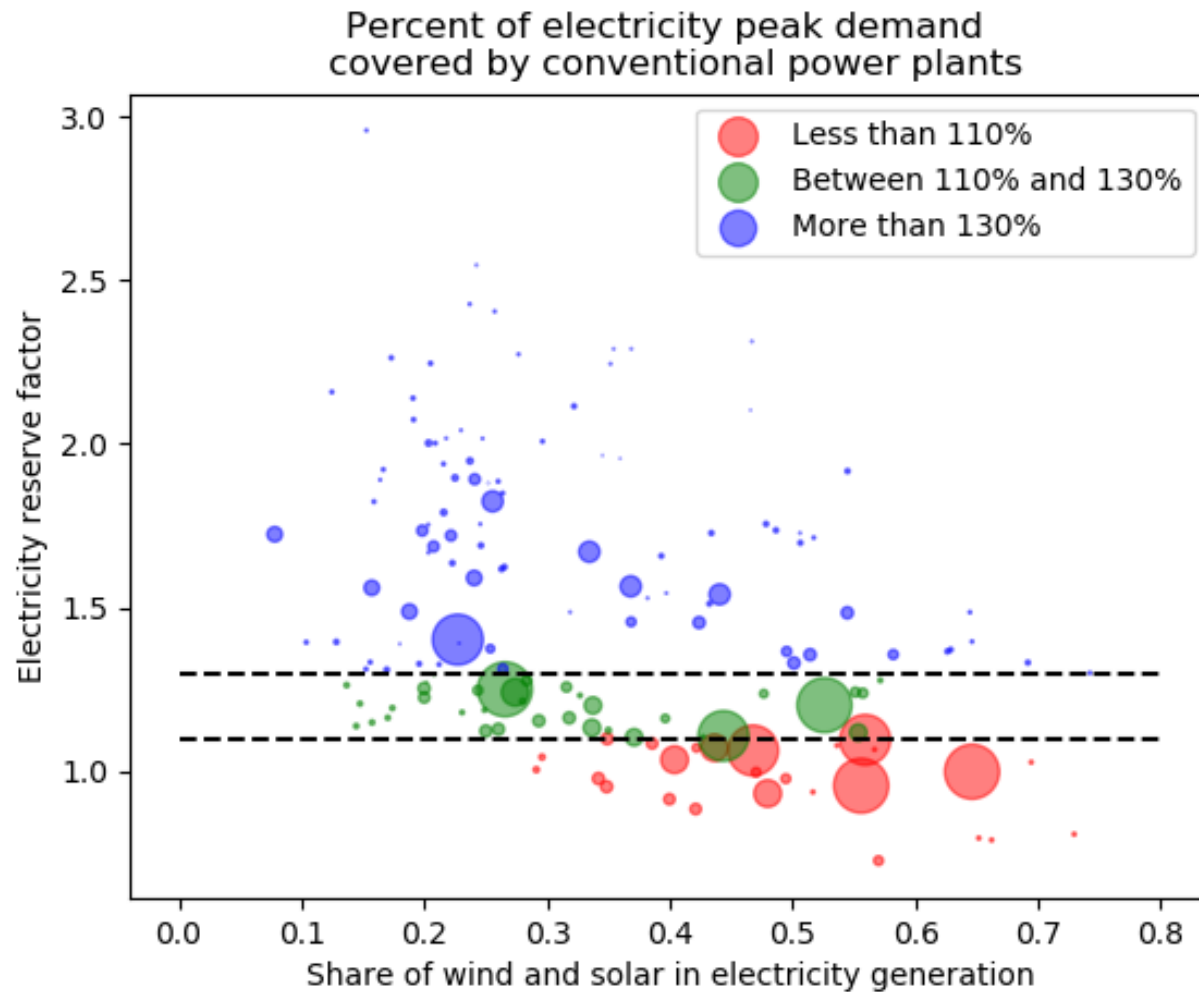
Reserve capacity factor 2030



Reserve capacity factor 2040



Reserve capacity factor 2050



List of countries with low reserve factor

- Need more interconnections between countries or regions to insure grid stability in:
 - Germany
 - Denmark (from 2035) – even for BAU scenario
 - Ireland
 - Netherlands
 - South Africa
 - Mexico
 - USA
 - Canada
 - China
 - India

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Conclusions

- The climate policies are positive effect on **availability** of European energy security:
 - Decrease energy dependency (included imports of fossil fuel).
 - Diversify primary energy consumption.
 - Better diversification of natural gas importers.
- Energy remains **affordable** in developed countries, however there is a risk for developing countries in which the energy bill increases faster.
- The EU and other large countries have to pay attention to **grid stability** in the case of high share of intermittent renewables.

Thank you for your attention

IPCC scenarios collected and assessed for WGIII AR5

CO ₂ eq Concentrations in 2100 [ppm CO ₂ eq]	Subcategories	Relative position of the RCPs ⁵	Cumulative CO ₂ emissions ³ [GtCO ₂]		Change in CO ₂ eq emissions compared to 2010 in [%] ⁴		Temperature change (relative to 1850–1900) ^{5,6}				
			2011–2050	2011–2100	2050	2100	2100 Temperature change [°C] ⁷	Likelihood of staying below temperature level over the 21st century ⁸			
								1.5 °C	2.0 °C	3.0 °C	4.0 °C
< 430	Only a limited number of individual model studies have explored levels below 430 ppm CO ₂ eq										
450 (430–480)	Total range ^{1,10}	RCP2.6	550–1300	630–1180	–72 to –41	–118 to –78	1.5–1.7 (1.0–2.8)	More unlikely than likely	Likely	Likely	Likely
500 (480–530)	No overshoot of 530 ppm CO ₂ eq		860–1180	960–1430	–57 to –42	–107 to –73	1.7–1.9 (1.2–2.9)	Unlikely	More likely than not		
	Overshoot of 530 ppm CO ₂ eq		1130–1530	990–1550	–55 to –25	–114 to –90	1.8–2.0 (1.2–3.3)		About as likely as not		
550 (530–580)	No overshoot of 580 ppm CO ₂ eq		1070–1460	1240–2240	–47 to –19	–81 to –59	2.0–2.2 (1.4–3.6)		More unlikely than likely ¹²		
	Overshoot of 580 ppm CO ₂ eq		1420–1750	1170–2100	–16 to 7	–183 to –86	2.1–2.3 (1.4–3.6)				
(580–650)	Total range	RCP4.5	1260–1640	1870–2440	–38 to 24	–134 to –50	2.3–2.6 (1.5–4.2)	Unlikely ¹¹	Unlikely	More likely than not	
(650–720)	Total range		1310–1750	2570–3340	–11 to 17	–54 to –21	2.6–2.9 (1.8–4.5)				
(720–1000)	Total range	RCP6.0	1570–1940	3620–4990	18 to 54	–7 to 72	3.1–3.7 (2.1–5.8)		More unlikely than likely		
>1000	Total range	RCP8.5	1840–2310	5350–7010	52 to 95	74 to 178	4.1–4.8 (2.8–7.8)	Unlikely ¹¹	Unlikely	More unlikely than likely	

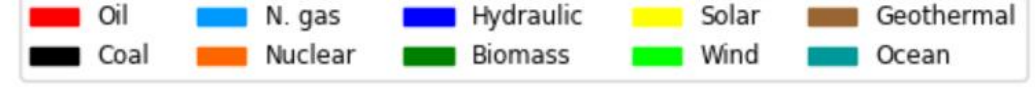
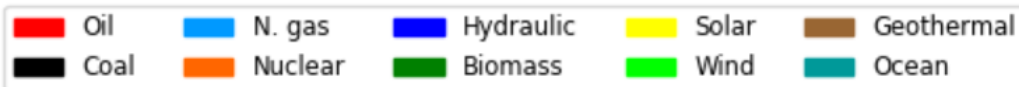
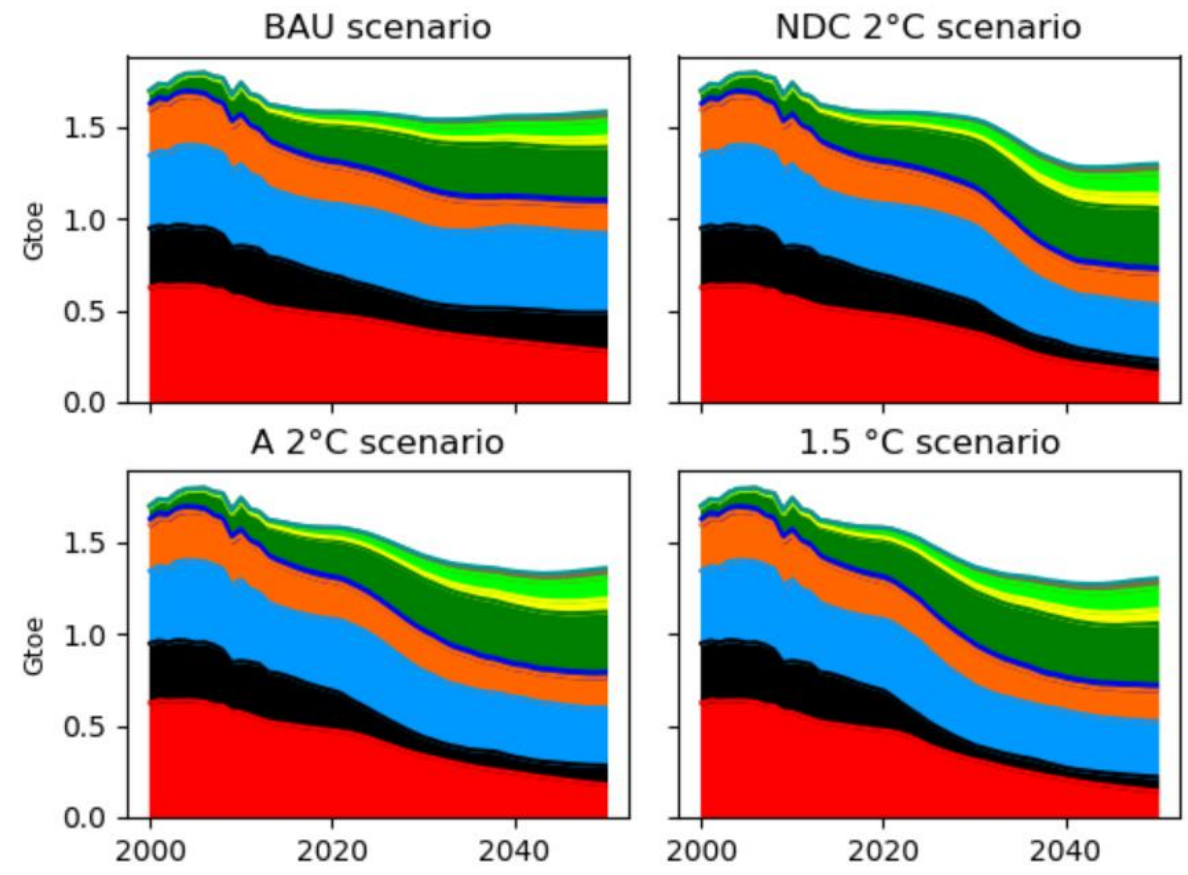
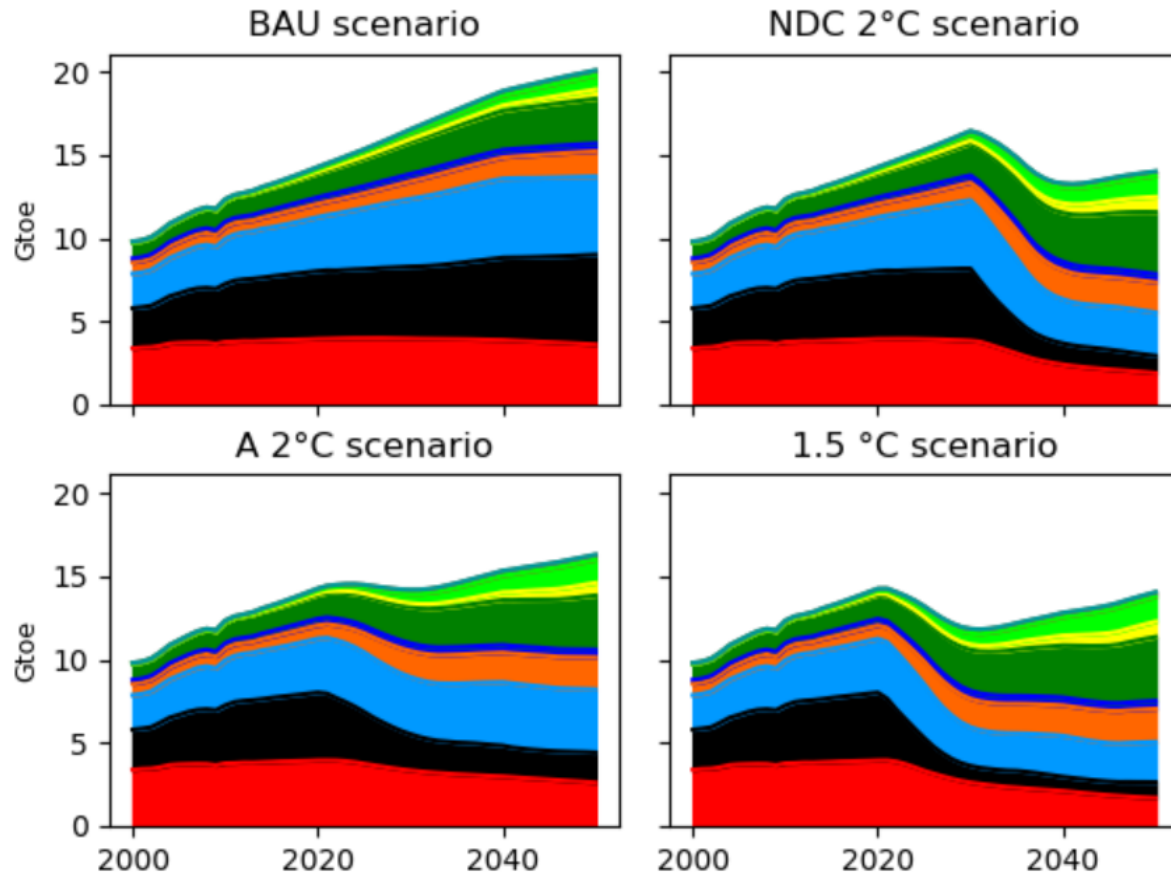
Source: Table SPM.1, Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, 2014



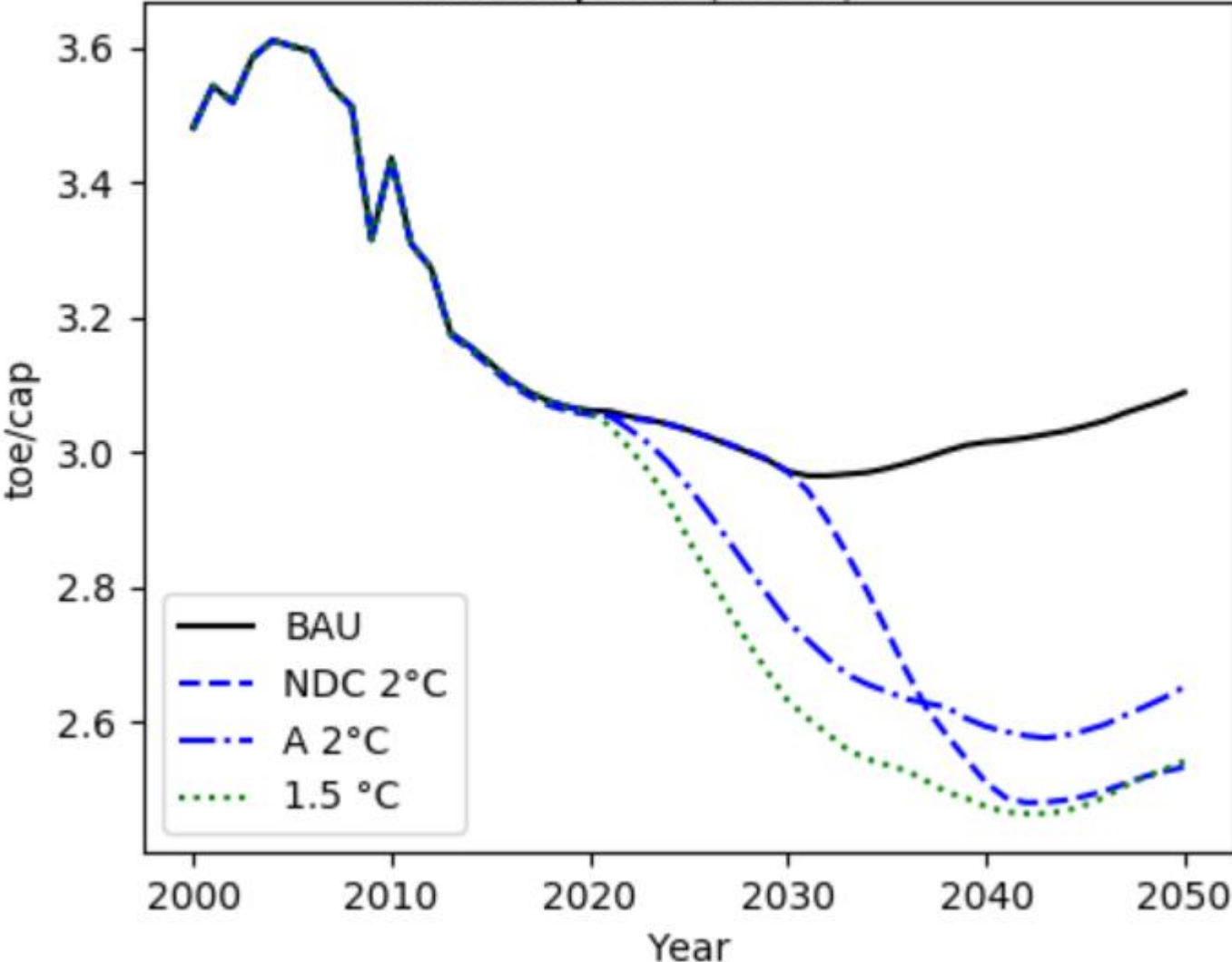
World and EU28 primary energy consumption

World

EU28



Per capita primary energy consumption (EU28)



Energy intensity of GDP (EU28)

